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   Prof. Norman West Bellamy
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   Patents ADP number *(if you know it)* — 359135l001

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4. Title of the invention

   Lining Pipelines using Thermoplastic Sheet and Strip.

5. Name of your agent *(if you have one)*

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DESCRIPTION

LINING PIPELINES USING THERMOPLASTIC SHEET AND STRIP

This invention relates to the lining of pipelines with a close fit lining with structural properties to prevent leaks and eliminate problems arising from corrosion and age.

Leakage is a major problem to the gas and water authorities and repairs or replacement of gas, water and sewage pipes are expensive operations. Leakage from gas pipes is dangerous and leakage from water pipes can average over 30% between reservoir and tap. Many pipelines are in need of refurbishment and the authorities generally seek long term solutions rather than piecemeal repairs. Thermoplastics such as polyethylene are the current preferred materials for relining the gas and water networks and can have design lifetimes of at least 50 years and expected lifetimes much longer. A number of pipe lining methods are available for lining small and medium diameter pipes but are not generally applicable for the lining of large diameter pipes. This absence of suitable lining methods for large diameter pipes mean that expensive replacement solutions often have to be implemented.

This invention has particular advantages over existing systems for lining pipes of medium and large diameters. In general, pipelining systems use materials and lining systems suited to their application and use. Linings for gas pipes, where gas containment is paramount, normally use standard or special polyethylene pipes, sometimes temporarily deformed, to insert into old cast iron host pipes. These structural 'sliplining' techniques take up large street footprints and become impractical for large diameter pipes, say 24 inches and above, and there are no generally acceptable methods for lining larger gas pipes up to 48 inches diameter and more. For water pipes with strict drinking water regulations, cement mortar linings have been replaced by spray-on resins to prevent corrosion and leakage, whereas polyethylene sliplining techniques are used for long term structural solutions. Cured-in-place polyester resin linings are popular for gravity sewer pipes where host pipe deformity is a problem and regulation less restrictive. Again, in both the water and sewer pipe industries, the lining of large diameter pipes present difficult problems and new or alternative solutions would be welcome.

The invention uses thermoplastic extruded sheet supplied on a roll or coil, which is readily available at low cost, and comes in a variety of widths up to 9m and thickness up to 100mm. Two forms of sheet are referred to in the text as 'thermoplastic sheet', which is relatively thin and wide, and 'thermoplastic strip', which is relatively thick and narrow. The invention covers the lining of the host pipe with a composite of thermoplastic sheet and strip where the thermoplastic is normally polyethylene.

This invention provides a means of lining a pipeline with a composite liner made from a tube of thin thermoplastic sheet, to provide gas or liquid containment, bonded to outer spiral wound thermoplastic strip, to give structural properties to the lining. These structural properties can range from a simple support backing, bonded to the thin inner sheet, in contact with the gas or liquid, to a fully structural liner capable of meeting operational specifications without the help of the host pipe. Installation of the basic materials for this composite structure is through a relatively small access pit

at each end of the pipe section to be lined. After preparation of the host pipe for lining, a long length of thermoplastic strip, with a width less than the internal diameter of the host pipe and thickness dictated by the structural requirements, is fed from a coil through a twisting unit, situated in the access pit, and then winched through the pipe to a spiral installation rig working back from the far end of the host pipe. The installed strip normally forms a tight spiral fit inside the host pipe with each turn lying in contact with its neighbour without the need of jointing or bonding. Normally a second spiral strip will be installed in the pipe with the opposite twist to complete the structural part of the composite liner. This would be followed by the insertion of thin thermoplastic sheet from a roll, with a width greater than internal circumference of the pipe to be lined, through a tube folding unit situated in the access pit, to form an overlapping tube that is winched through the pipe to be lined. The final lining operation is the seam bonding of the sheet tube and the bonding of the sheet tube to the underlying spiral lining.

The components of the composite liner can be assembled into various configurations to meet particular pipe lining specifications. The preferred structural configuration comprises two opposite wound spiral strip layers with one inner sheet layer whereas semi-structural linings may only require one spiral and one sheet layer. Extra sheet layers between two spiral layers provide the means of resisting external liquid ingress or a means of leak detection. Three sheet layers with two spiral layers can provide a smooth lining inside host pipe with severe deformities. Other configurations are possible to meet particular design requirements.

The preferred method of bonding the composite pipe components is by infrared radiation. This is carried out either, by an air pressurised rig that travels along the inside of the pipe or, a pressurised air bladder transparent to infrared, where both methods expand the liner components tightly onto the inside wall of the host pipe. The rig is fitted with a infrared lamps which radiate short wave infrared energy though the thin inner sheet tube to weld the overlapping seam and also selected areas of the sheet tube to the underlying spiral winding. For this welding process to be successful the liner materials have to have certain properties as explained in the next paragraph.

Many thermoplastic materials in thin sheet form, such as natural polyethylene, are partially transparent to short wave infrared radiation in their natural state but can be made opaque to infrared when coloured, preferably black, by dye, ink or with embedded particles or fibres made from absorbing materials such as carbon. Short wave infrared radiation, which avoids the peak absorption spectra of many thermoplastics, passing through a transparent sheet in pressure contact with a underlying sheet with opaque material at the interface will weld the sheets together by virtue of the heating and melting of the opaque material at the interface. Also, because the transparent thermoplastic material absorbs some of the infrared energy, it will warm up and soften allowing it to form to shape under applied pressure. Therefore, the favoured material for the composite liner is polyethylene where the spiral layers are made from black polyethylene and the sheet tube layer made from natural polyethylene with an opaque black edge for the under surface of the overlapping seam.

From a pipe lining perspective a useful feature of the infrared welding process described in the previous paragraph is the distinctive change of colour, from a light grey to dark grey as seen from within the pipe, due to the surface wetting effect of the molten plastic at the interface during welding. This colour change provides an important means of verification that the weld and lining process is complete.

An alternative method of bonding the composite pipe components is by ultrasound. This is also carried out either by an air pressurised rig that travels along the inside of the pipe or, a pressurised air bladder, both of which and expand the liner components tightly onto the inside wall of the host pipe. The rig is fitted with a ultrasonic welding tools which radiate ultrasonic vibrations though the thin inner sheet tube to weld the interface in the overlapping seam and the interface between selected areas of the tube and the underlying spiral winding. For successful welding the liner materials must be thermoplastic in order that the ultrasonic vibrations induce a thermal rise at the bonding interface to melt and weld the component parts. This bonding method can be faster and penetrate thicker sheet than the infrared method but requires a higher continuous pressure contact on the wall of the liner.

A further alternative method of bonding the composite pipe components is by electrofusion. Electrofusion is a common method of bonding fittings to thermoplastic pipes and involves electrically heating of embedded wires at the interface of the two welding surfaces. The wires are placed in the surfaces of the fittings to be bonded in factory conditions and, on site, are heated by a predetermined current for a predetermined time to ensure the interface surfaces melt and mechanically bond together. Application of electrofusion in this pipelining system involves embedding wires in appropriate places on the sheet layer in a factory rig, inserting the sheet tube into the host pipe and air pressurising the tube onto the spiral lining by means of an inserted bladder tube into the pipe. Electrical connections are made to the ends of the embedded wires and the fusion welding process carried out for the whole lining. The bonding method is independent of the thickness of the sheet and is very quick to weld. However the heating wires have to be carefully pre-installed in the surface of the sheet material sheet in factory conditions.

It should be noted that many pipelines are not straight and have internal irregularities such as joints, projecting lateral connections and misalignment of pipe sections. In these pipes thin walled liners made from flat sheet will often tend to kink or buckle when forced by a pressure to deform to the internal shape of the pipeline. In a pipeline with many irregularities it is particularly difficult to seam weld reliably when the overlapping welding surfaces are distorted prior to welding and may not be in continuous contact even under high pressure. This invention provides the solution to the problem by pre-lining the pipe with an underlying relatively smooth surface which also provide structural support to the thin walled liner. Simple spiral winding made of compatible strip has this smoothing property, together with the structural properties, especially if made into a double spiral with an opposite hand winding. Such spiral lining structures have smooth inner surfaces that enable the firm contact to be made with the thin walled sheet tube as required by various bonding methods such as infrared, ultrasonic and electrofusion welding. The composite liner described is therefore very flexible in its ability to overcome pipeline deformities and can adapt to some variation in diameter and straightness in the sections being lined.

Although pipelines are thoroughly cleaned prior to lining the welding surfaces of the sheet tube have to be kept clean to guarantee the quality of the welded seam. There are a number of ways to protect the cleanliness of the sheet material during the installation process. One method is to wrap the sheet tube with plastic film before the tube passes into the host pipe. This wrapping can also be used to confine the diameter of the tube to enable easier insertion into the host pipe. The wrapping can be removed by the pressurised lining rig either by bursting the wrapping or cutting it. An alternative method is to bond a protection film to bridge across the edges of the sheet tube prior to insertion into the host pipe. This latter method completely protects the seam welding surfaces since the film can be left in place during the welding process. In practice it is unlikely that wrapping methods will be required to keep the welding surfaces clean because the spiral layers themselves provide a protective barrier inside the host pipe and therefore a clean environment for welding inside the pipe.

Calculations show that composite polyethylene liner comprising spiral strip and sheet layers have a pressure capability only a few percent less than the equivalent standard polyethylene pipe with the same wall thickness. Configurations of the composite liner described can be used to line medium, large and very large diameter pipes, say up to 96 inches, with wall thickness to match SDR11 to SDR26 specifications and installed lengths between access pits of 1500m. Close fit linings for variable pipe diameters can be achieved and bends negotiated where the radius is down to 20 diameters. This invention provides an extremely versatile pipe lining system with installation advantages and only uses low-cost basic materials.

The versatility of the composite structure allows it to be reinforced with alternative or additional spiral layers wound with other materials such as high performance plastic, fibre reinforced thermoplastic, filament woven braid or metal strip. This choice of spiral strip materials enables composite linings to be designed to a much higher specification than standard pipes or normal pipe linings.

The gas and liquid containment integrity of the lining is dependent on the integrity of the seam welding of the sheet lining. Where verification of the gas or liquid tightness and structural strength of the seam is deemed necessary, the following method can be carried out during acceptance tests of the completed lining. This involves double welding the seam with a space between the welds that can be air pressurised to check for any leaks occurring along the entire length of the seam. If necessary this thin air passage can be enlarged by groove created by the extrusion process or cut prior to installation. In practice, where infrared welding is used, the passage cross section is adequate for the purpose due to local heat distortion created by the welding process. The testing procedure is to make tapings into the passageway at both ends of the lining section, check for air flow along the passage and then pressurise the passageway according to a prescribed procedure. Any leaks would indicate a problem with at least one of the seam welds. No leak confirms both welds are satisfactory and the seam verified as sound.

An alternative to the seamed sheet tube internal lining is to insert an extruded thin wall thermoplastic pipe into the pipe being lined and bond this to the underlying spiral wound layer in the same manner as the seamed tube. This thin walled tube could be supplied in lay flat form on a roll, inserted in a folded form, expanded to fit the lining

by the pressurised welding rig and then welded to the underlying spiral wound layer as previously described.

An alternative to the structural spiral layers is to insert short lengths of thick walled pipe section in various folded forms to enable them to pass down the pipe on a travelling rig that will insert them to provide a continuous pipe lining run. These sections will be bonded to the thin sheet lining to give a composite structure with a pressure rating equivalent to standard pipes.

Service connections to supply gas or liquid to users have to be disconnected before lining commences and then reconnected after lining. These connections are normally accessed through pits and use special ferrule connectors to seal to the lining within the host pipe. This type of expanding ferrule connector is particularly suited to making service connections to the composite lining described. Since service connections are normally made to the top of the host pipe it is preferable that they avoid the seam of the sheet tube. This can be achieved at installation by inserting the seam at the bottom of the host pipe.

Installation of thermoplastic, such as polyethylene, linings are normally carried out between access pits where short sections of the host pipe have been cut out to allow installation access. After completion of a lining section the ends of the lined pipe sections have to be rejoined in the access pit. This requires end connections, normally flanges, to be made to the linings to enable short sections of connecting pipe to be inserted. In the case of connections for normal polyethylene linings, polyethylene flanges are heat fusion welded to the pipe lining ends. This fusion jointing method is particularly suited in this invention for connecting the composite lining to standard polyethylene pipe inserts. The fusion welding process not only welds the flange to the lining but welds each layer of the composite lining together to give a fully structural termination to the lining.

The preferred embodiments of the invention will now be described with reference to the accompanying drawings in which:

FIGURE 1 shows a cutaway view of a preferred configuration of the composite liner within the host pipe.

FIGURE 2 is a cross section of a structural configuration of the preferred composite liner.

FIGURE 3 is a cross section of a semi-structural configuration of a composite liner.

FIGURE 4 is a cross section of a structural configuration of a composite liner with leak detection facility.

FIGURE 5 is a cross section of a structural configuration of a composite liner suited to lining pipes with severe deformities.

FIGURE 6 shows the installation arrangement to feed and twist the thermoplastic strip into the pipeline.

FIGURE 7 shows the spiral lining arrangement using a spiral installation rig within the pipe.

FIGURE 8 shows the installation arrangement to feed and form the thin thermoplastic sheet into a rolled up tube that is winched through the pipe.

FIGURE 9 shows the travelling welding rig which expands the rolled up sheet tube, welds the seam of the sheet tube, and welds the sheet tube onto the underlying spiral wound lining.

FIGURE 10 shows detail of the seam welding arrangement.

FIGURE 11 shows detail of the seam welding arrangement with a fan providing additional air pressure to ensure contact at the welding interface.

FIGURE 12 shows detail of one seam welding arrangement to produce a double weld.

FIGURE 13 shows cutaway detail of the double welding of the seam to provide a means of verifying the integrity of the seam.

FIGURE 14 shows cutaway detail of the electrofusion method of welding the seam.

FIGURE 15 shows one arrangement of a service connection.

FIGURE 16 shows the arrangement of making end connections.

Figure 1 shows a cutaway view of a preferred configuration of the composite liner within the host pipe 1. A thermoplastic strip forms a spiral lining 2 tightly wound onto the inside surface of the pipe with each turn in contact with the neighbouring turn. Inside this lining there is a second spiral strip lining 3 again tightly wound onto the inside surface of the first lining but wound in the opposite direction. These freely wound spiral layers form a stable structural assembly held in place by the host pipe. However, the structure is not gas or water tight and hence an inner liner 4 comprising a seamed thermoplastic tube is bonded to the inner surface of the spiral structure. The structural qualities of this composite lining compare to standard thermoplastic pipes of similar wall thickness and the flexible design using basic materials lends itself to the lining of large diameter pipes.

Figure 2 shows a cross section of a host pipe 1 with a thin seamed tube inner lining 4 backed by two thick spiral wound strip linings 2 & 3, wound in opposite directions, to give a composite liner that has sufficient structural strength to be used either, as a semi-structural lining that reinforces the host pipe to give a structural combination equivalent to a standard pipe or, as a fully structural lining that can match the pressure specification of standard pipes of similar wall thickness. Typically, a pipe lining with a 17.6 SDR (standard dimensional ratio) would be 600mm diameter, 34mm wall thickness made up of two spiral layers of 15mm thick each and a sheet tube layer of 4mm thick.

Figure 3 shows a cross section of the host pipe 1 with a thin seamed tube inner lining 4 backed by one thick spiral wound strip lining 2 to give a simple composite liner. This configuration is gas and liquid tight and has sufficient structural rigidity to support itself within a pipe or if necessary resist external pressure due to water or gas ingress.

Figure 4 shows a cross section of the host pipe 1 with a thin seamed tube inner lining 4 backed by two thick spiral wound strip linings 2 & 3 together with a thin seamed tube outer lining 5 to give a composite liner that can have sufficient structural strength to match the pressure specification of standard pipes of similar wall thickness. This configuration can also provide the means of detecting gas or liquid leakage through the liner by monitoring the pressure or flow in the space between the inner and outer seamed tube linings. This is due to the enclosed porous spiral structure that allows leaking gas or liquid to flow along the length of a lined pipe section.

Figure 5 shows a cross section of the host pipe 1 with a thin seamed tube inner lining 4 backed by two thick spiral wound strip linings 2 & 3 together with a thin seamed tube outer lining 5 and a thin seamed tube intermediate lining 6 to give a composite liner that can have sufficient structural strength to match the pressure specification of standard pipes of similar wall thickness. This configuration helps to provide smooth internal surfaces to enable gas and water tight welding when the host pipe suffers severe deformities.

Figure 6 shows a coil of thermoplastic strip 7 of a preferred width approximately equal to half the diameter of the host pipe 1 and a thickness dictated by the lining specification. The strip is drawn into the exposed pipe end in the access pit 8 by a winch, at the far end of the pipe section to be lined, and twisted into stretched helix 9 by rotating the coil 7 and associated guide rollers 10 about the bearing 11 fixed to the supporting stand 12. If the strip needs extending a new coil can be installed and the strip butt-fusion welded to the tail end of the previous coil using standard techniques. When the strip reaches the spiral winding rig (see Figure 7), initially located at the far end of the pipe, the feed from the coil is held until the rig is ready to line the pipe. This spiral winding rig then draws further twisted strip from the coil to line the pipe and effectively consumes one twist of the strip for every spiral turn carried out by the rig.

Figure 7 shows the spiral winding rig 13, held by a cable of control winch, used to line the pipe with thermoplastic strip fed by the installation rig described in Figure 6. The twisted strip 9 is drawn through powered guide rollers 14 into a freely rotating rig 13, on guide wheels 15, inside the host pipe 1 and fed by powered 16 pinch rollers 17 to create a spiral lining 2 on the inside wall of the host pipe. Suitable guides are provided inside the rotating rig 13 to translate the stretched helical twist 9 in the incoming strip to the tight helical feed required to line the pipe. The lining process requires careful control of the longitudinal travel, by means of the winch and strip tensions, and the feed direction of the pinch rollers 17. Mechanical and electrical sensing of the edge of the previous spiral turn can provide the means of such control. Reaction on the pinch rollers by the spiral winding action forces the freely rotating rig 13 to both turn and travel down the pipe until the strip lining process is complete. A useful facility is that the spiral winding rig can be stopped at any time, for say inspection, and reversed to unwind the spiral if required.

Spiral winding of strip with a normal rectangular cross section causes a distortion of the cross section of the strip normally described as edge turn-up. This causes a uneven inner surface of the spiral lining which is undesirable but not detrimental. Solutions, if required, are to feed the strip through profiled powered pinch rollers either when leaving the roll or in the spiral winding rig in order to induce a compensating lateral curvature.

The equipment described in Figures 6 and 7 wind a clockwise spiral as seen from the strip feed end. The equipment is easily reversible in order to wind neighbouring spiral layers in an anti-clockwise direction.

Figure 8 shows a roll of thermoplastic, normally polyethylene, sheet 18 having a required width to cover the internal circumference of the host pipe plus some overlap. For welding by infrared the bulk of the sheet material is natural coloured, to enable infrared transmission through the sheet, but with one edge of the sheet coloured black, to enable infrared absorption at the interface and hence heating and welding. Two examples of enlarged cross sections of the black sheet edge are shown in the diagram inserts, 19 & 20, where the black opaque material is either on the surface of the sheet 19 or through the sheet 20. The width of the roll, say 3.5m for a 1m diameter pipe, may be too wide for a practical access pit and therefore the roll may need mounting above ground. This means the sheet feed has to curve into the access pit to line up with the exposed pipe without kinking during formation of lining tube. The solution to this problem is to fold the sheet into a flattened tube to enable it to bend about the wide axis in order to minimise the distortion of the sheet. In the figure the sheet is fed from the roll 18 through guide rollers 21 to series of guides and rollers 22 to turn up, or turn down, the edges of the sheet 23 and then fold them over to make a flat tube 24. The formed sheet 24 has its total width reduced and fits into a relatively small access pit 25. The flat tube cross-section can now be curved through a series of rollers 26 and low-friction guides into a horizontal direction. To help to maintain the sheet profile without kinking around the curve an internal tongue 27 is fitted and held by a support through the slot at the top, or the bottom, of the flat tube. Further rollers 28 and guides help the flat tube to expand into a round tube 29 as it enters the end of the host pipe 1 taking care that the natural coloured material overlaps the black edge 19 or 20 as seen from inside the tube. A winch located at the far end of the pipe provides the force 30 required to pull the sheet through the forming rig and along the pipe. If it is required to keep the sheet lining tube clean a plastic film wrapping can spun around the sheet tube as it enters the host pipe. This can be burst by the rig air pressure or cut by an attachment on the lining rig, shown in Figure 9, to allow the tube to expand into contact with the pipe wall.

Figure 9 shows a lining rig 31 designed to complete the lining process by welding the sheet tube lining 32 to the underlying spiral lining 3. At the same time the rig welds the seam of the sheet tube 32 to form a gas and liquid tight inner lining. Behind the rig the lined host pipe is pressurised by a fan installed in a sealed stop at the starting end of the pipe. The lining rig 31 has a front shield 33, fitted with sliding seals to give air tightness, and the air pressure drives the rig along the pipe at a velocity controlled by the winch feeding out cable 35. The rig 31 runs on two sets of radial wheels and supports the seam welding box 36 and a number of sheet welding boxes 44 containing the preferred infrared lamps.

The air pressure forces the lining components tightly onto the host pipe wall, ensures the sheet welding surfaces are kept in pressure contact during welding, and reduces any distortion of the lining during welding and cooling. These sheet welding boxes can weld the sheet tube to the underlying spiral layer, either as a continuously line weld or intermittently to create a spot weld pattern. Cooling of the welding operation is provided by allowing some air 39 to bleed through the welding boxes and rig members to the low pressure side of the shield.

The welding boxes 36 and 44 can rotate on the bearing 37 to allow the seam welding box 36 to follow the seam along the pipe using mechanical or electrical sensors. The edges of the welding box 36 have a sliding seal to run along the seam and the box is additionally pressurised by the air fan 38. An alternative arrangement is to fit a sealed membrane over the edges of the seam welding box 36 that will exert a pressure on the welding overlap as the rig travels along the seam. This membrane needs to be transparent to infrared and to be heat resistant to prevent burning by the heat; polyester sheet is a suitable material. These arrangements ensure the overlapping surfaces of the seam are kept in pressure contact to meet the conditions required to make a good weld. Without this local pressurisation the seam surfaces may only make line contact rather than the essential full contact across the width of the seam welding box.

Verification of the welding process is carried out by onboard CCTV cameras and by later inspection. Good continuous welds are indicated by distinctive colour change of the welded area. On completion of the lining process, purpose made couplings are connected or fusion welded to the ends of the lining and the lined section pressure tested and leak tested in accordance to gas or water regulations.

Figure 10 shows an infrared welding box 36 used to weld the overlapping seam of the preferred polyethylene sheet tube. The host pipe 1 is lined by two spiral strip layers 2&3 and the sheet tube layer 4 with the overlap 40. The lower overlap surface has a black polyethylene surface 41 to absorb the infrared that penetrates through the upper natural polyethylene overlap sheet to heat, melt and weld the interface. The welding box 36 is mounted on the guide arm 42 and contains the infrared lamp 43 that provides the infrared radiation. Figure 10 also shows two of the infrared sheet welding boxes 44 that weld the sheet tube to the underlying black spiral layer. Normally there will be 4 to 10 of these boxes, depending on the diameter of the pipe, equally distributed around the inside circumference of the lining. These boxes can weld either a line weld or spot weld through the sheet as the lining rig travels along the pipe.

Figure 11 shows a special arrangement of Figure 10 to ensure adequate contact pressure at the welding interface during the welding process. A fan 38 pressurises the welding box thereby providing additional air pressure on the surface of the seam to be welded. This avoids the possibility of the seam only making seal contact along the edge of the underlining overlap due the air pressure within the pipe and leaving the top overlap free.

Figure 12 shows a special arrangement of Figure 10 or Figure 11 to enable the infrared welding box 36 to weld a continuous double weld along the seam. A shield

46 between the infrared lamp and the seam splits the infrared radiation into two beams to weld two separate parallel continuous welds 41. The seam verification groove or space 45 lies between these two welds.

Figure 13 shows a cutaway view of a section of an infrared welded seam of the sheet tube layer. The top overlap sheet 40 has a groove 45 at the interface along the length of the lining to provide a passageway for pressurised air used to verify the integrity of the seam welds. The two welds 47, alongside the passageway, seam the sheet tube and also seal the passageway 45. The dark lines 48 on the surface of the top overlap sheet indicate the welding process has been successful.

Figure 14 shows a cutaway view of a section of an electrofusion welded seam of the sheet tube layer. The top overlap sheet 40 has a groove 45 at the interface along the length of the lining to provide a passageway for pressurised air used to verify the integrity of the seam welds. The embedded wires of the two electrofusion welds 49, alongside the passageway, seam the sheet tube and also seal the passageway. Dark lines on the surface of the top overlap sheet can indicate the welding process has been successful provided the thickness of the sheet is not too great.

Figure 15 shows the service connection to connect the customer to the supply pipeline. The connection to the pipe is normally made at the top of the pipe to provide easy access and to avoid any liquid, in the case of gas pipes, or any solids that may accumulate at the bottom of the pipe. The connection tapping 50 shown is similar to commercial connectors purposely designed to connect to water or gas pipes lined with polyethylene linings. These connectors can be fitted either when the pipe is not of use or when under working pressure. In the drawing the body 51 of the fitting is screwed into the wall of the lining and a special expanding washer or cone 52 is pushed through into the inside surface of the pipe lining. The nut 53 is tightened and the washer or cone seals expand under pressure on to the inside of the lining to give a gas or water tight connection. The customer's connection is then made to the fitting through a valve.

Figure 16 shows the end connection system required to connect lined sections together or to connect to the continuing host pipe. Polyethylene pipes and polyethylene linings are normally butt welded together by a fusion welding process to form long lengths. Where access connections are required flanges are welded to the pipe ends by the same process to enable connection or disconnection to be made with the use of bolts or clamps. The same system can be employed with the composite lining by simply welding flanges 54 to the whole cross section of the lining 2,3&4. In the drawing the end of the lining is shown projecting from the end of the host pipe where it can be clamped and prepared for fusion welding. A polyethylene flange is aligned to the end of the lining 55 and then fusion welded together. All layers of the lining will be welded to the flange and to each other to make a fully structural and gas or water tight connection.

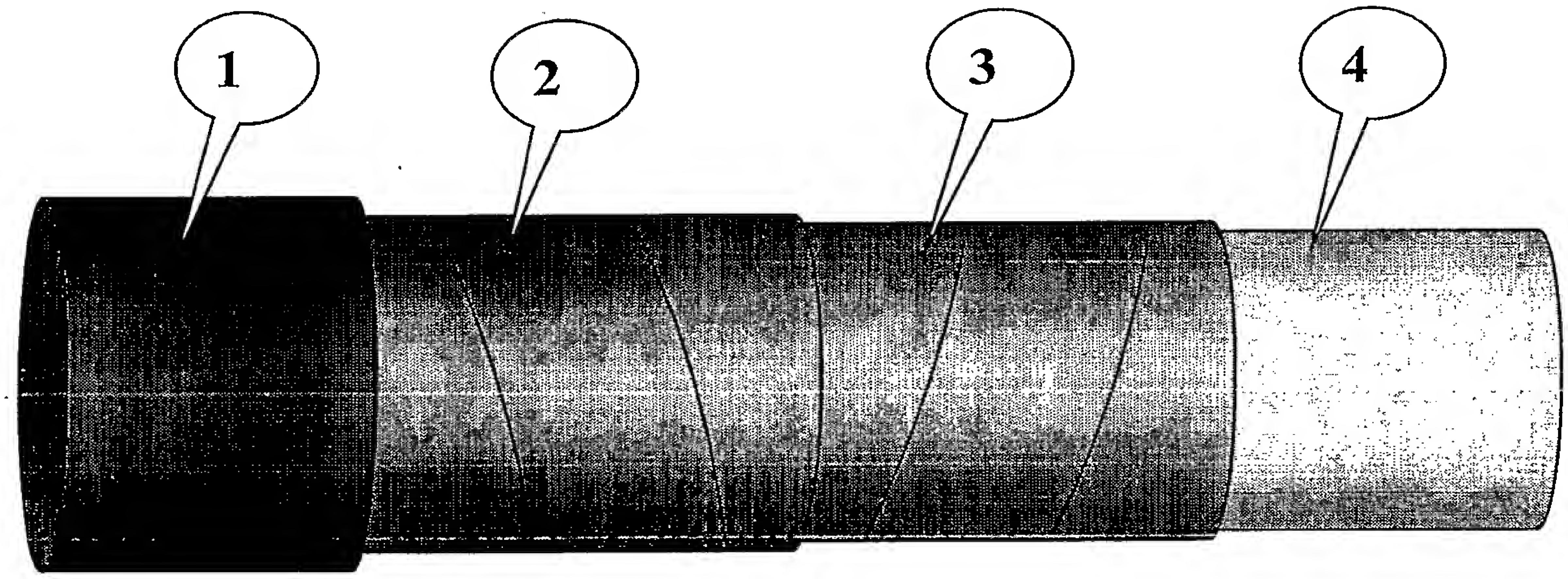


Figure 1

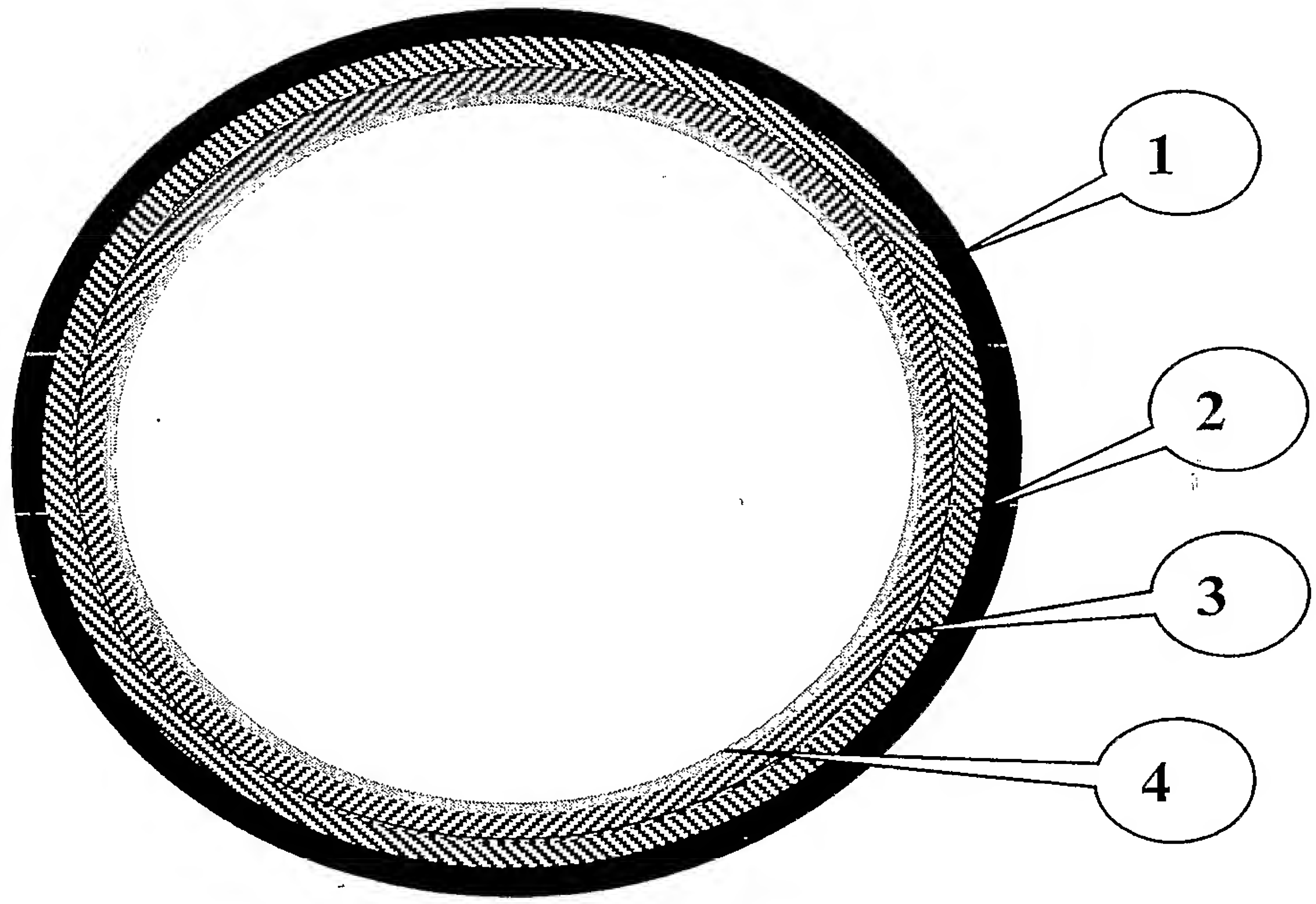


Figure 2

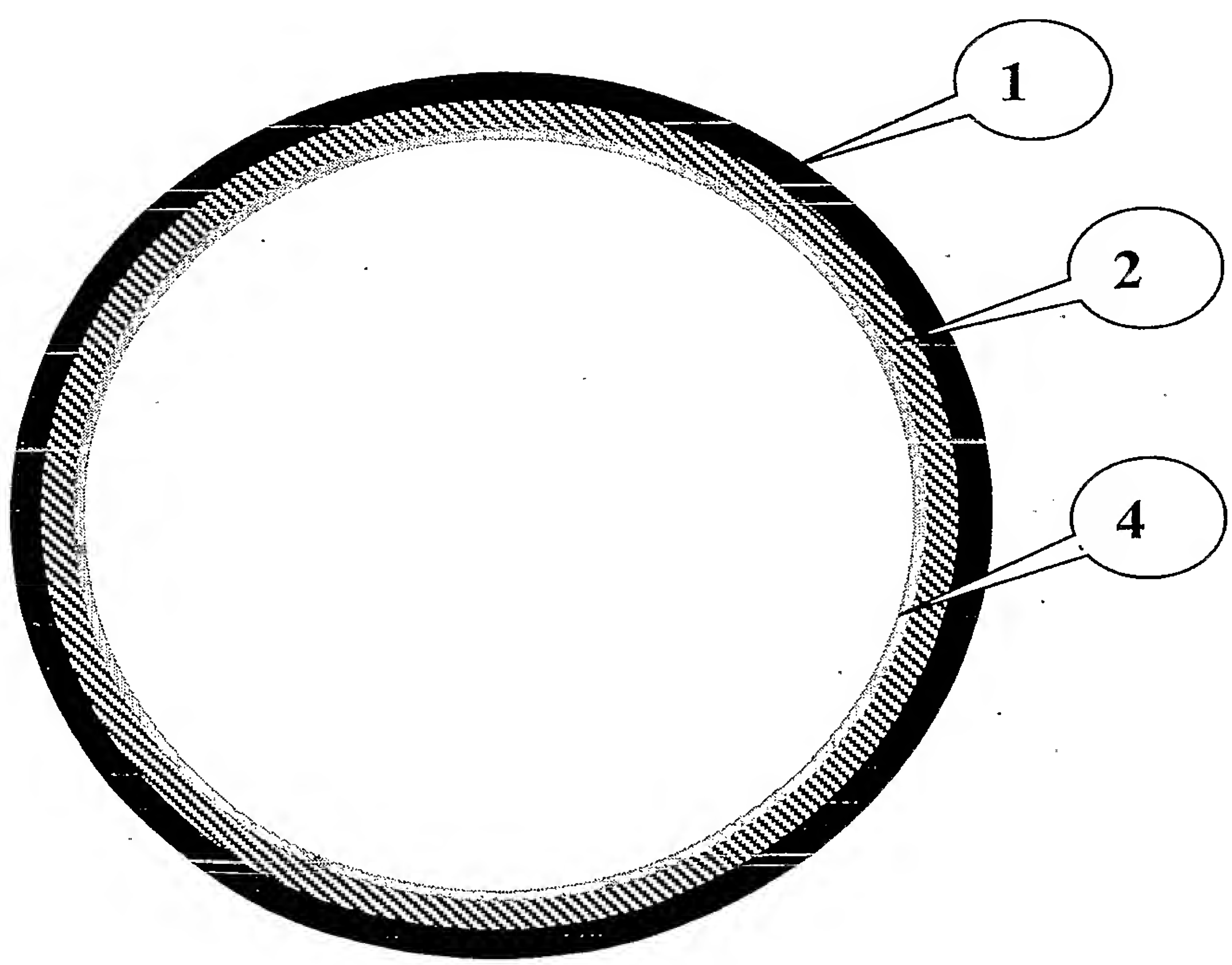


Figure 3

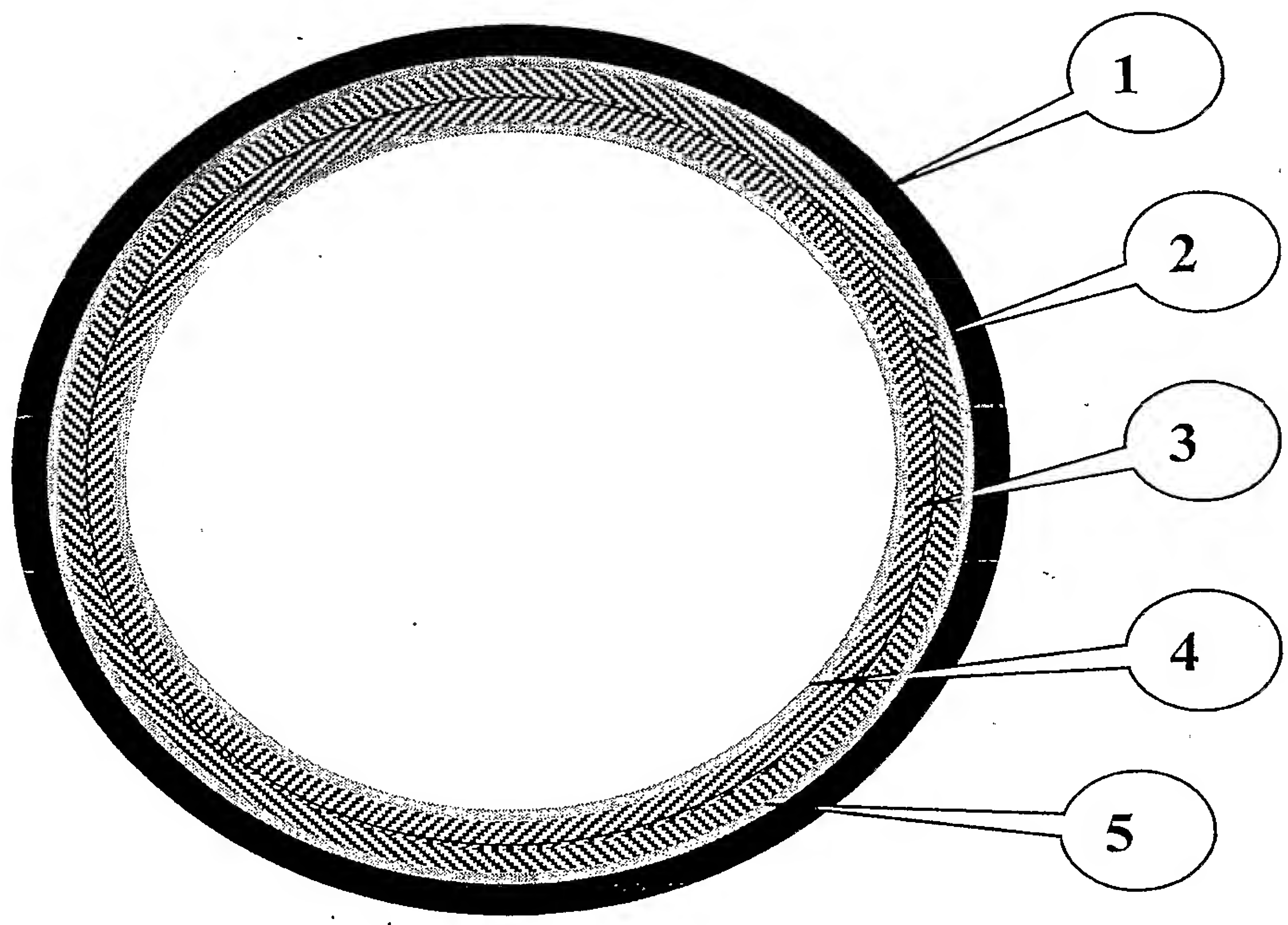
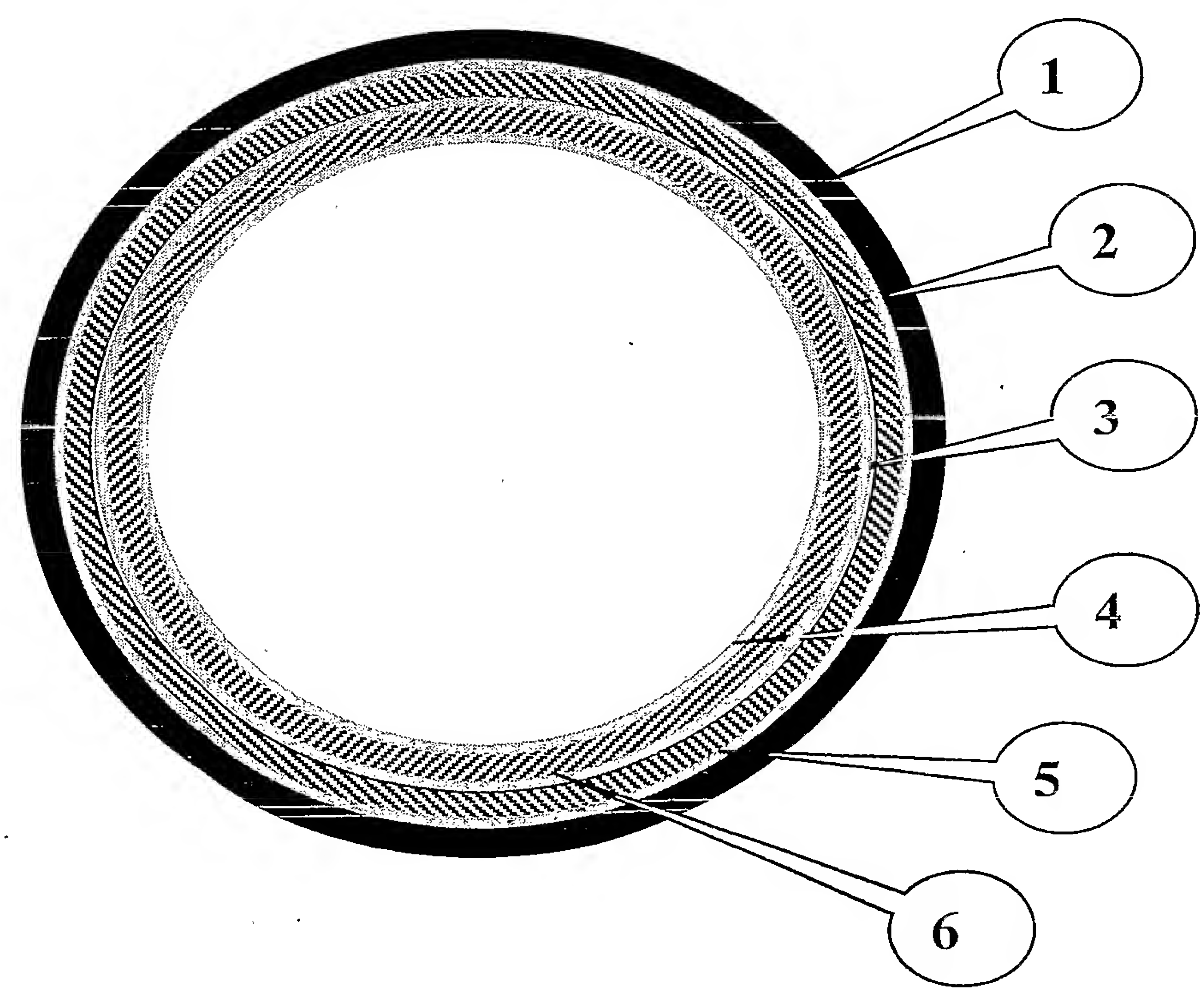


Figure 4



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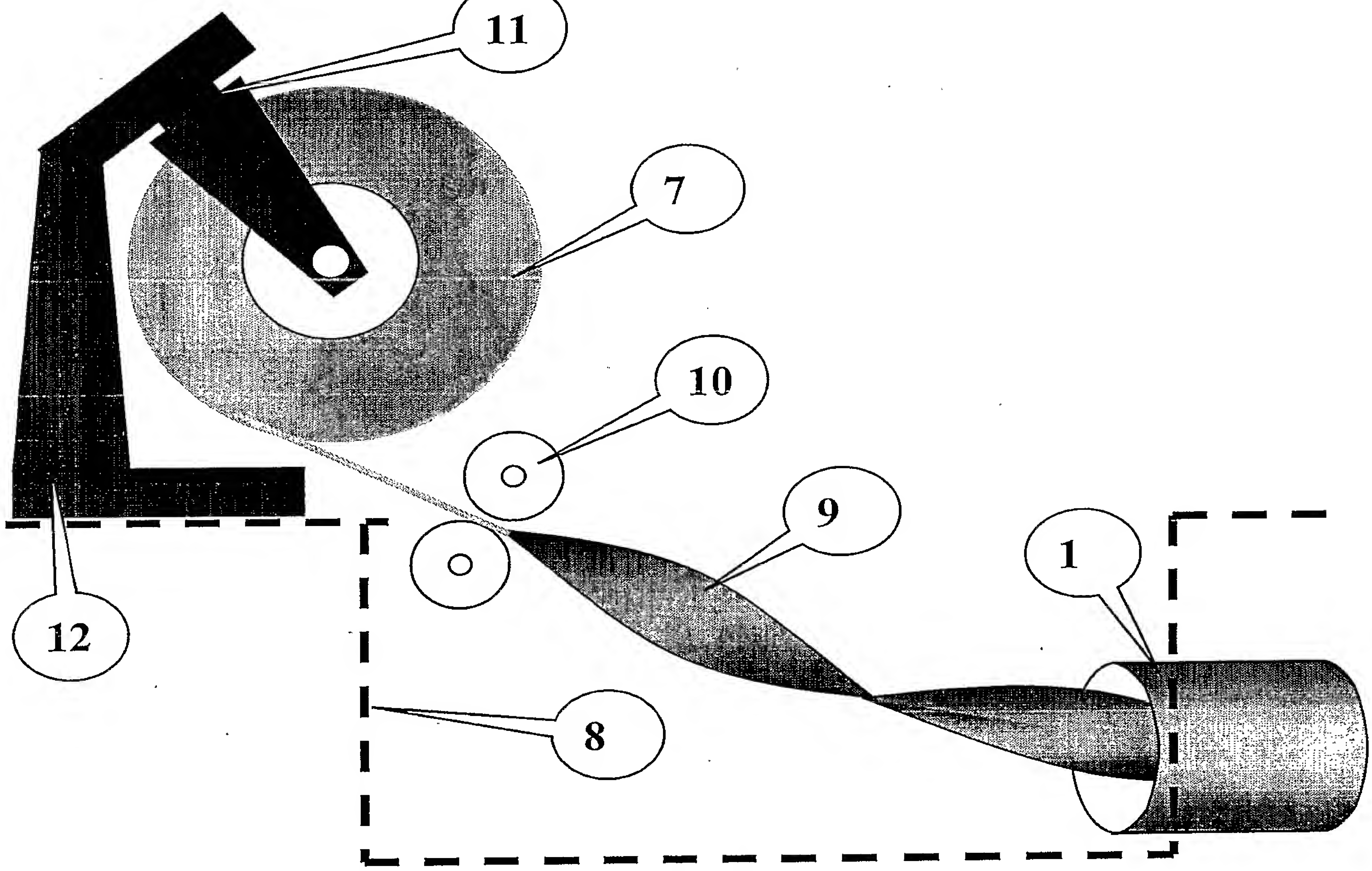

Figure 6

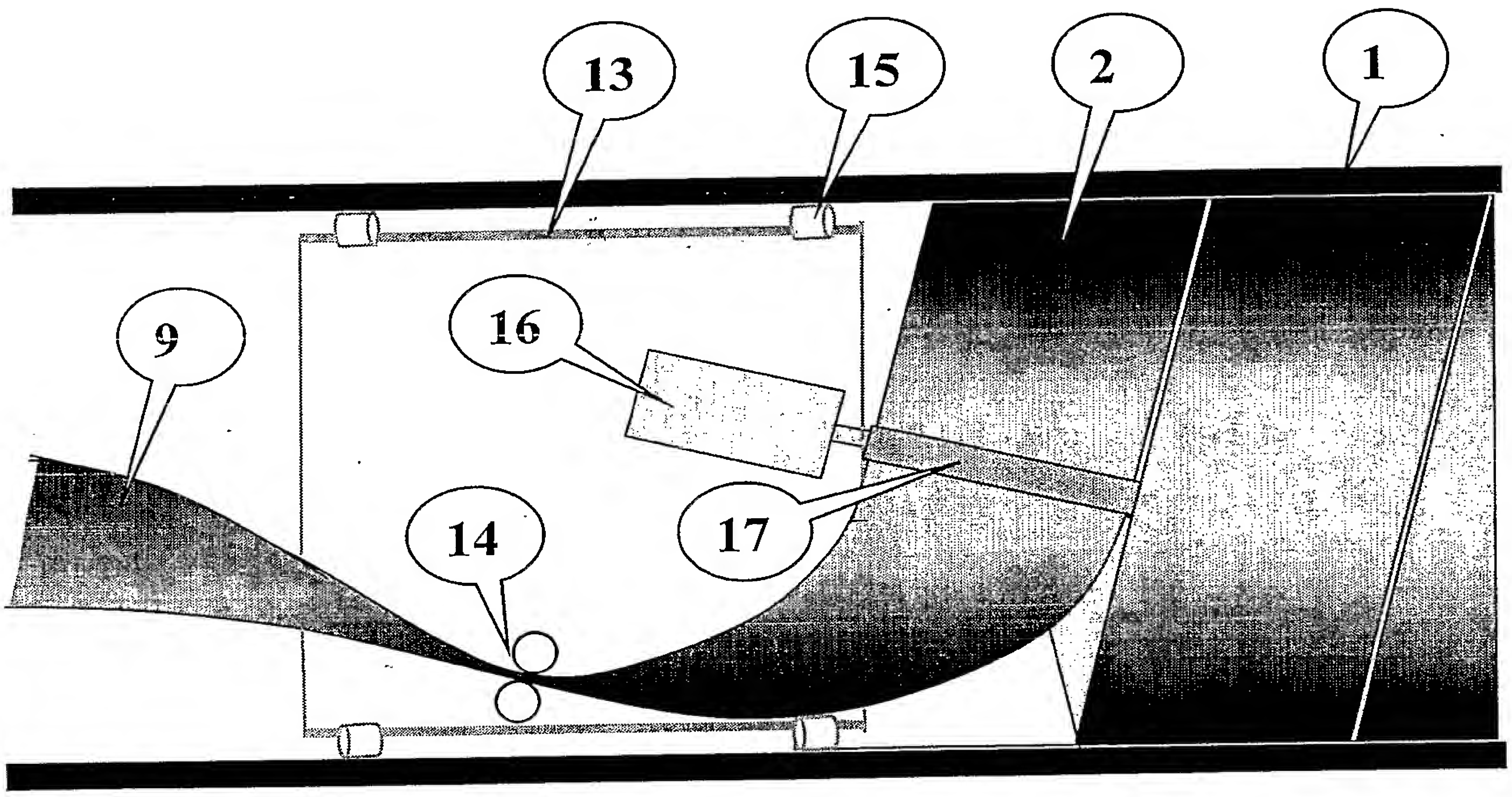

Figure 7

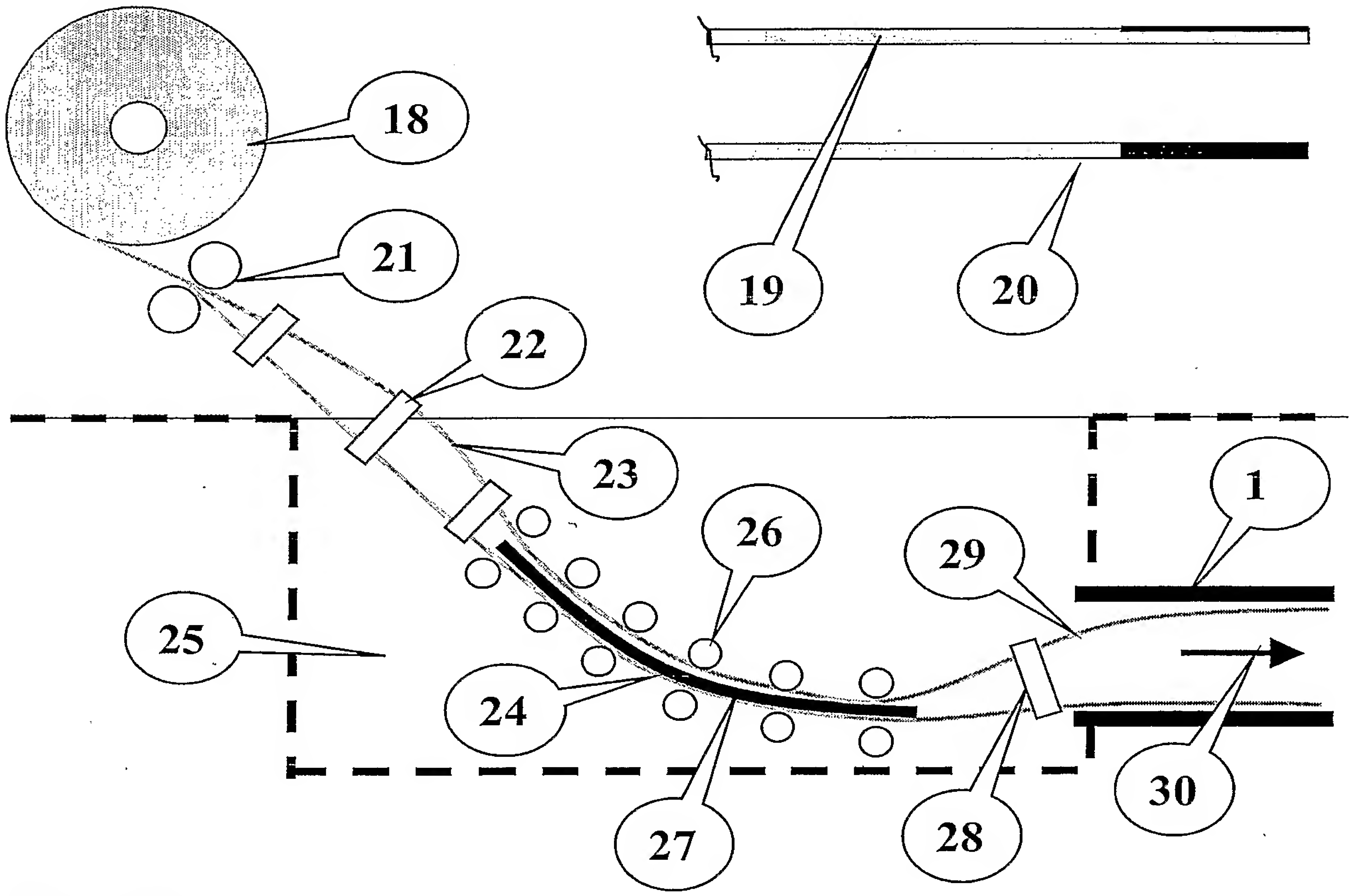

Figure 8

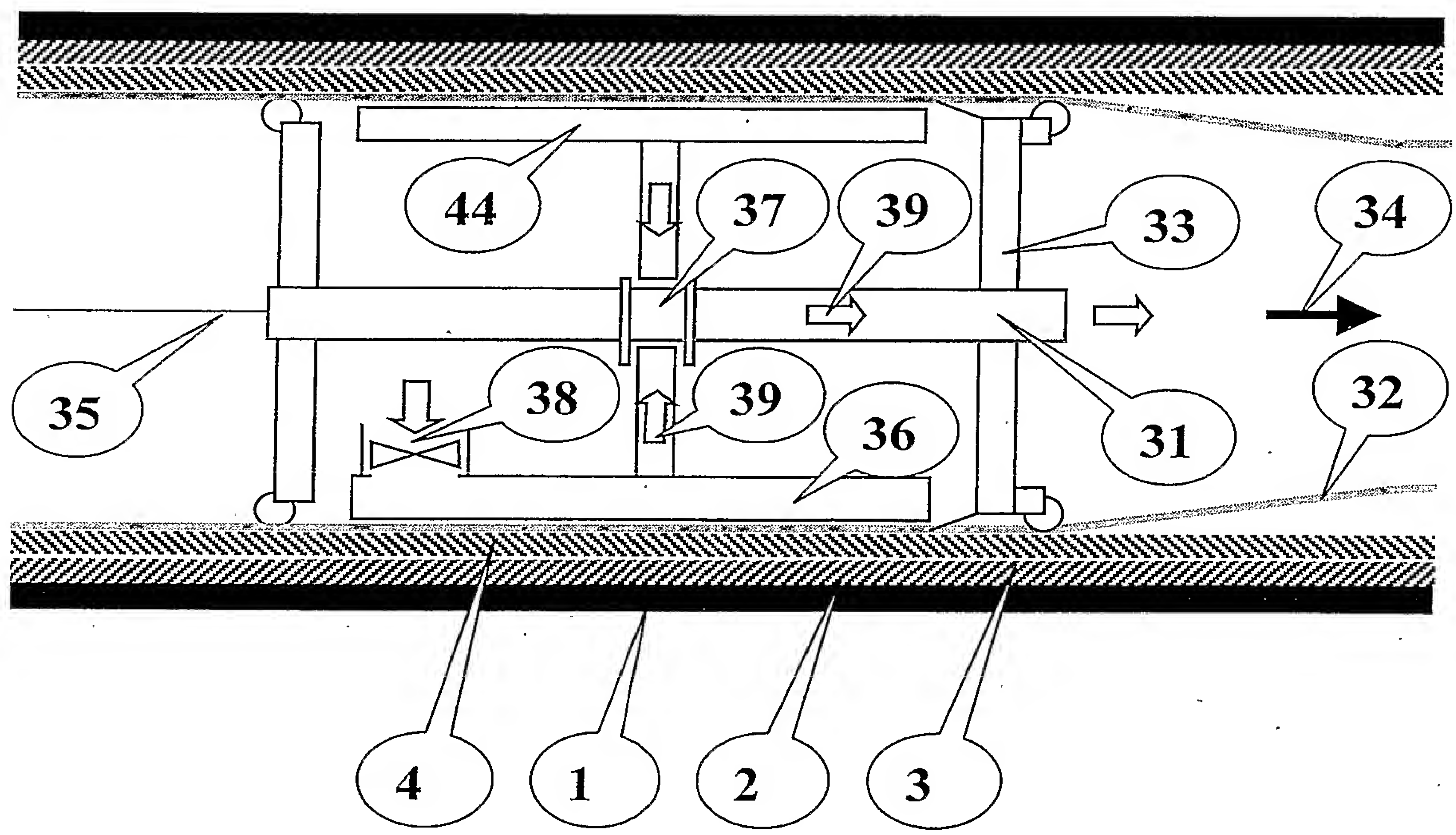

Figure 9

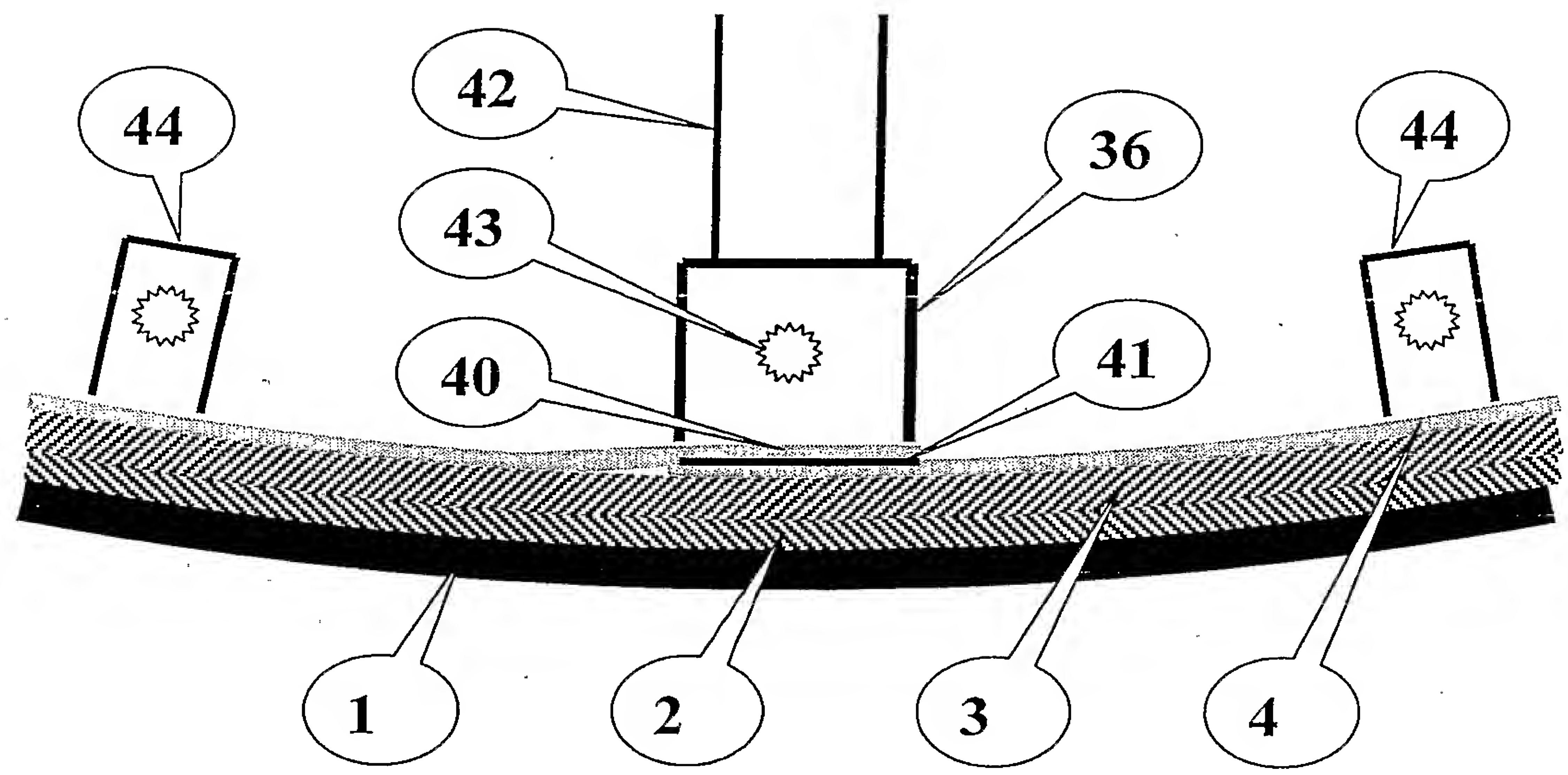

Figure 10

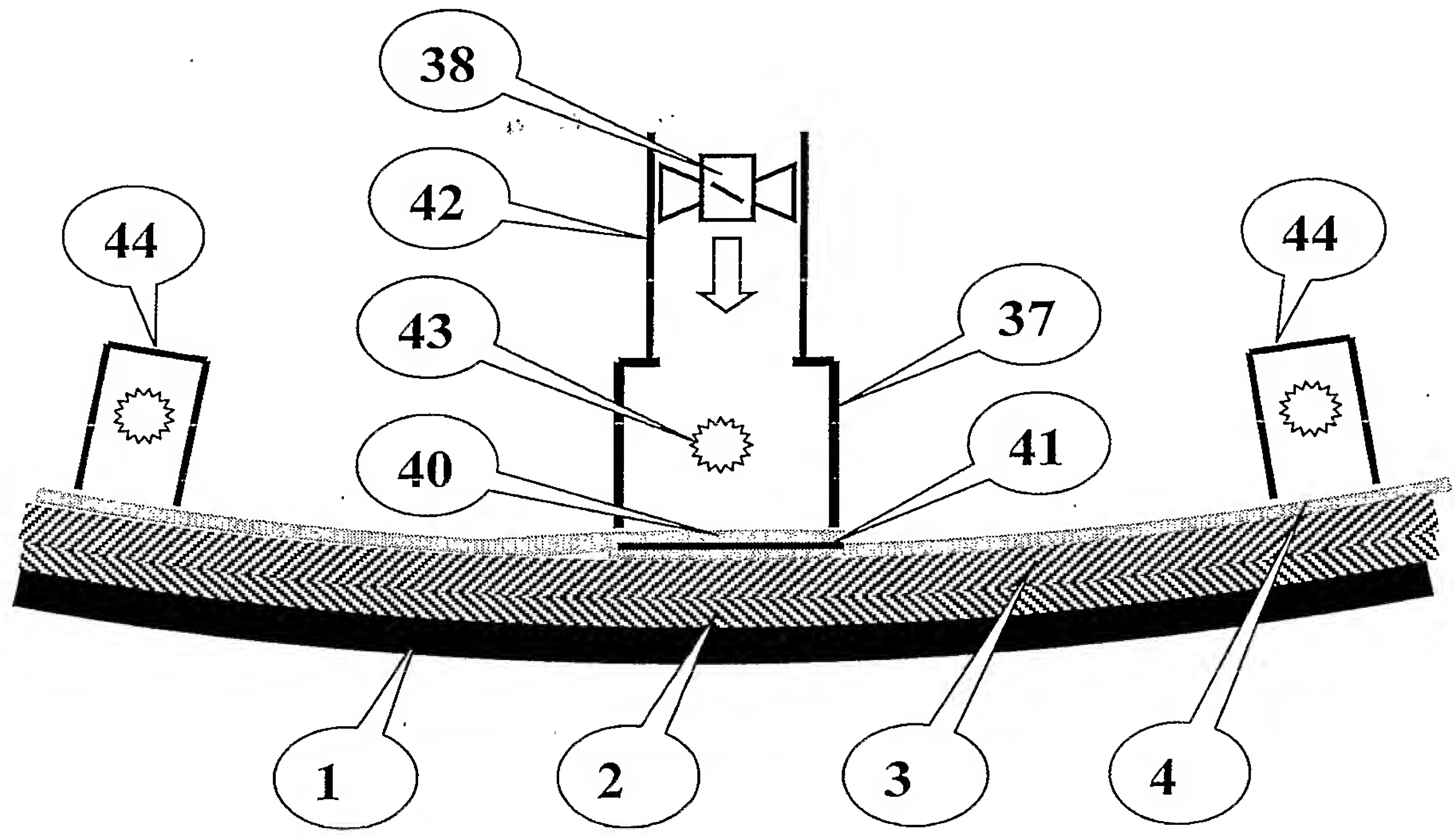

Figure 11

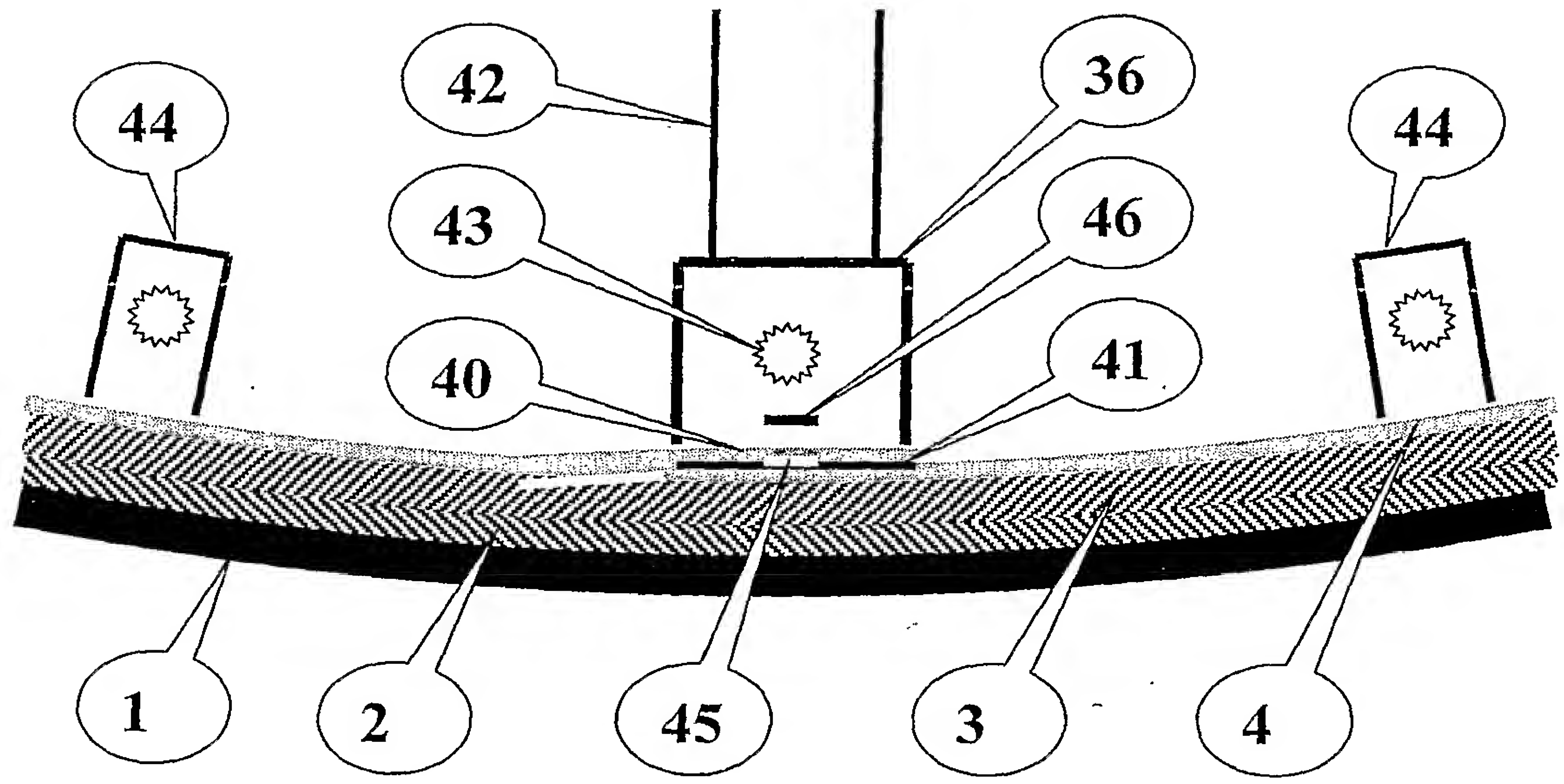

Figure 12

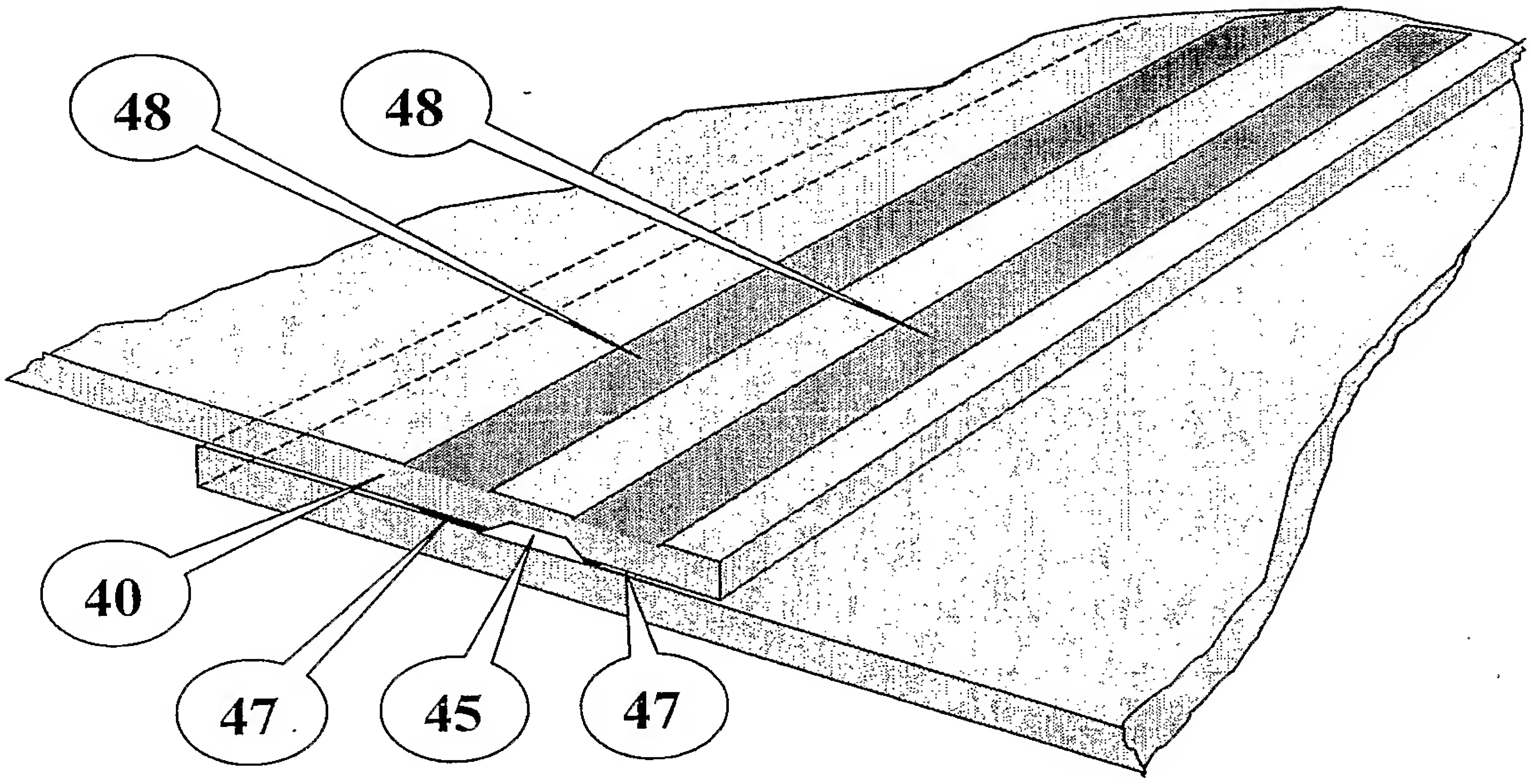

Figure 13

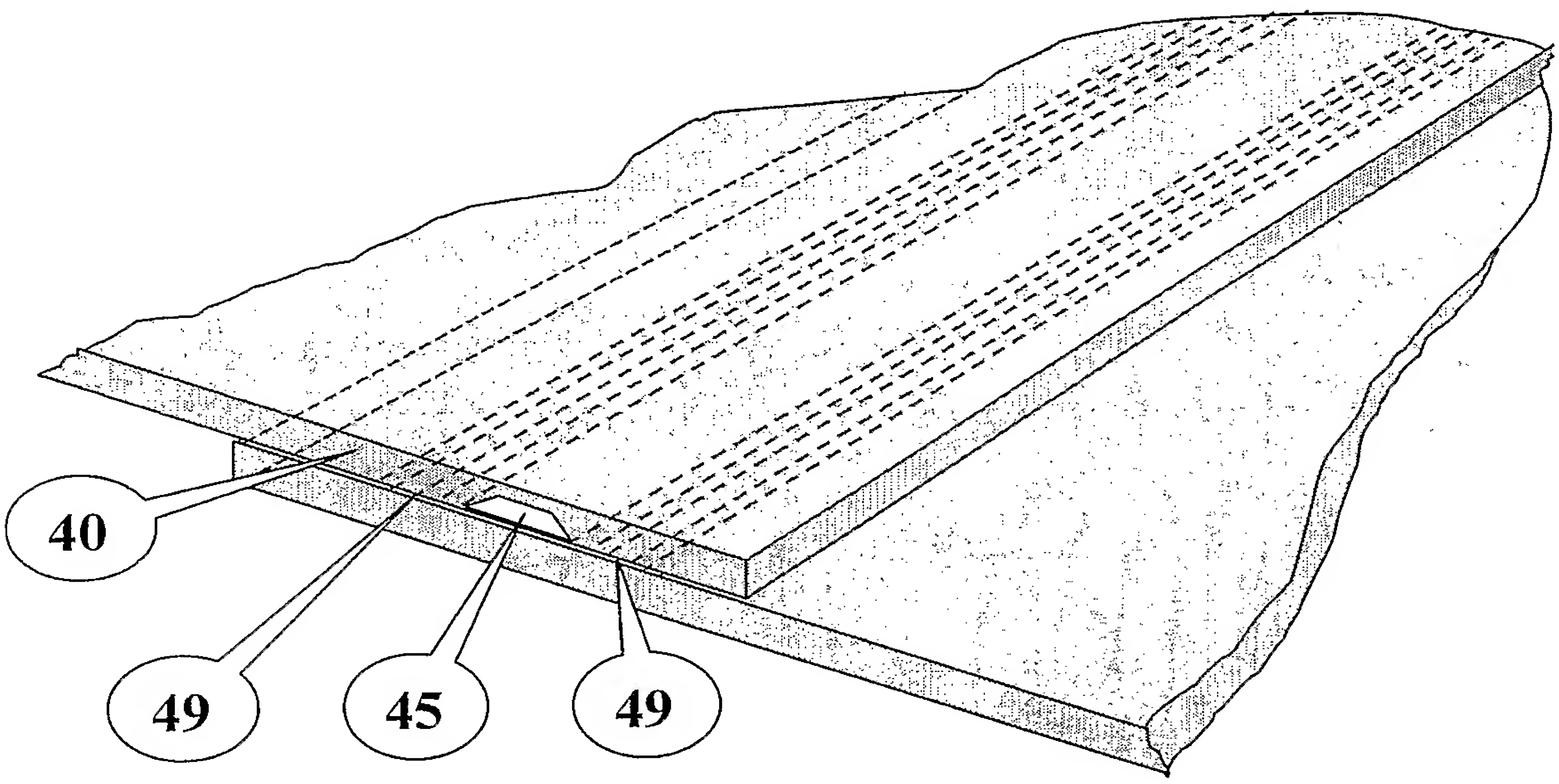

Figure 14

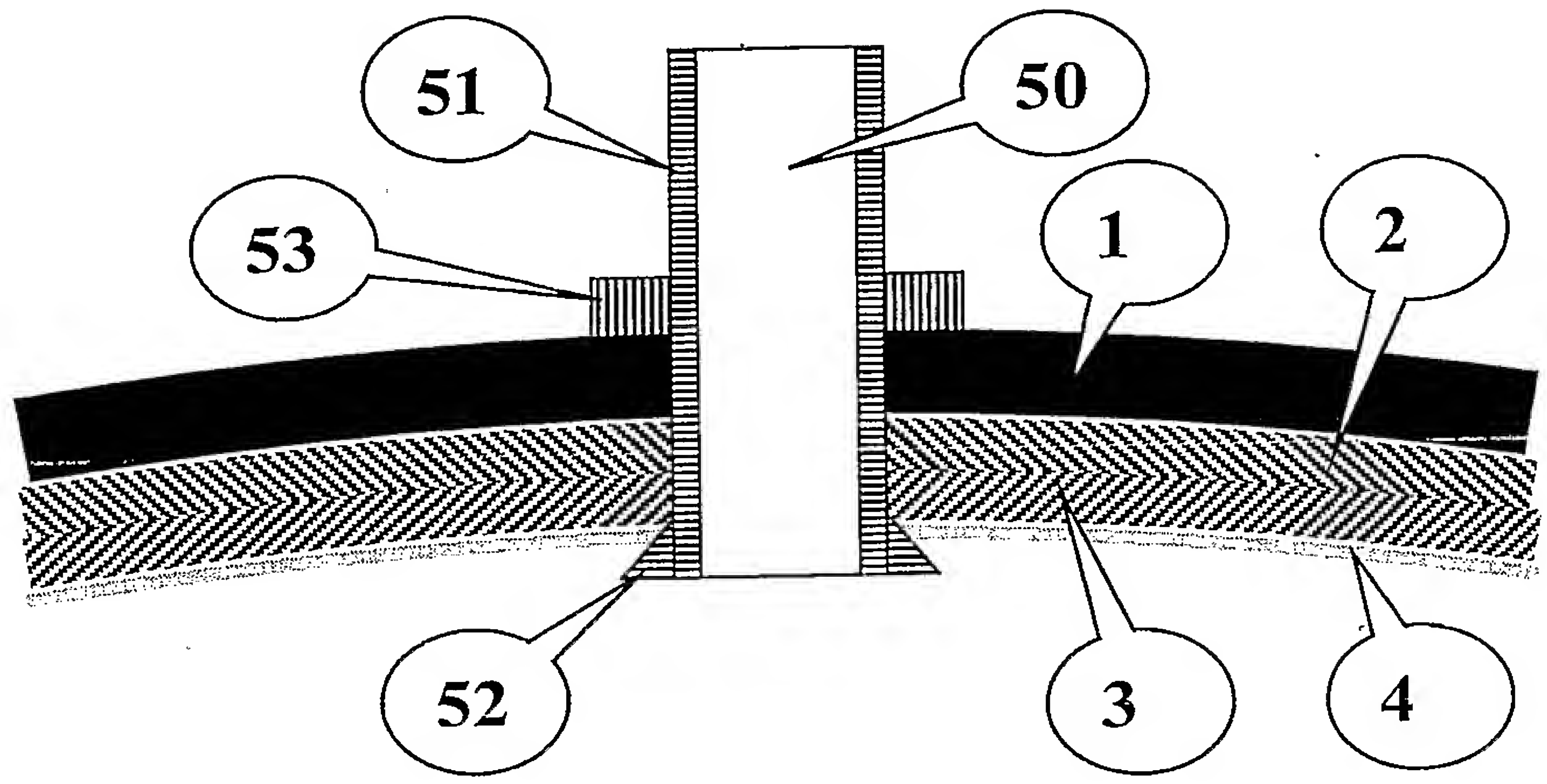

Figure 15

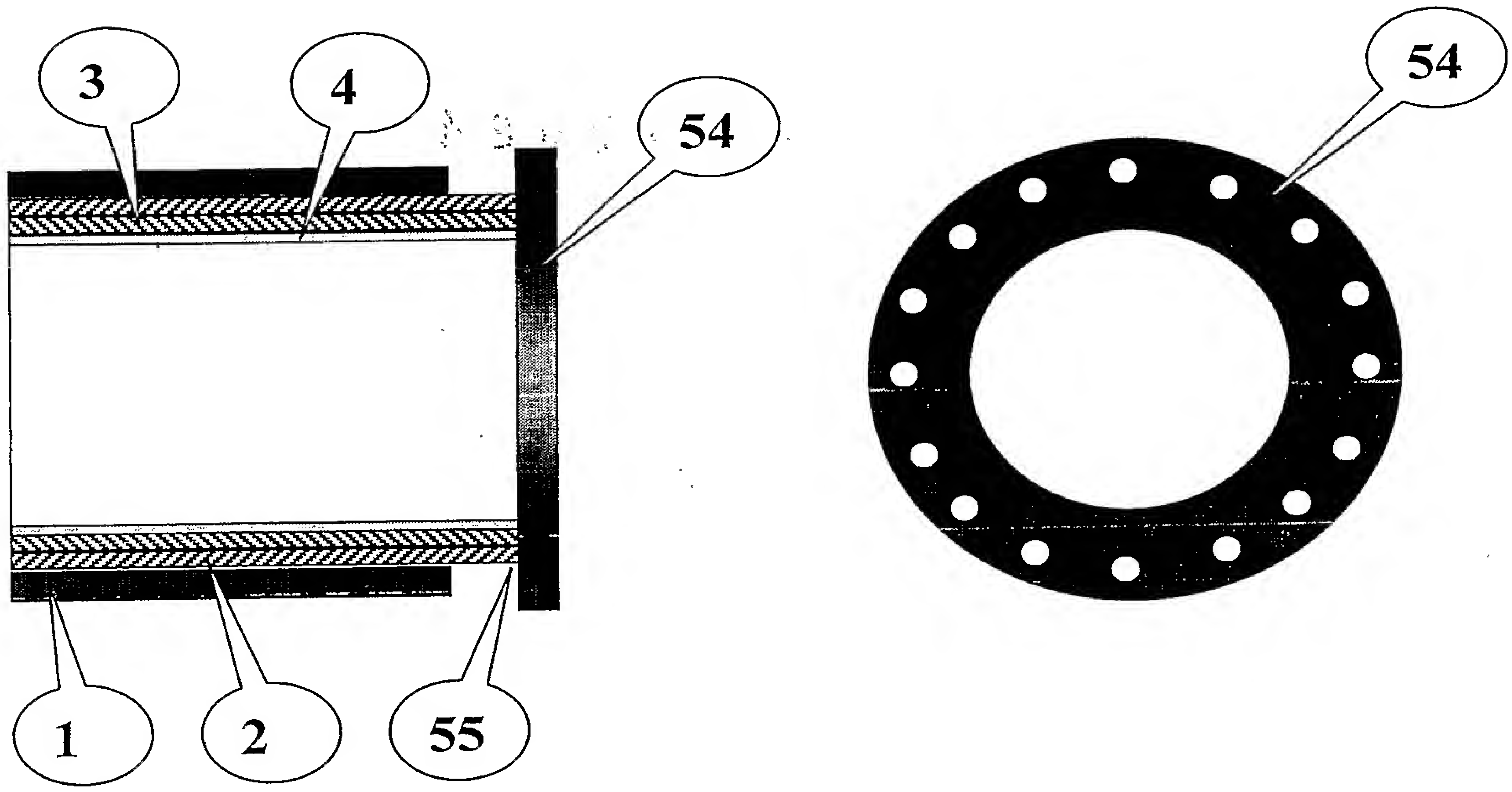

Figure 16